Advance pre-operative chlorhexidine reduces the incidence of surgical site infections in knee arthroplasty

Michael G. Zywił • Jacqueline A. Daley •
Ronald E. Delanois • Qais Naziri • Aaron J. Johnson •
Michael A. Mont

Received: 6 May 2010 / Revised: 5 June 2010 / Accepted: 6 June 2010 / Published online: 20 June 2010
© Springer-Verlag 2010

Abstract Surgical site infections following elective knee arthroplasties occur most commonly as a result of colonisation by the patient's native skin flora. The purpose of this study was to evaluate the incidence of deep surgical site infections in knee arthroplasty patients who used an advance cutaneous disinfection protocol and who were compared to patients who had peri-operative preparation only. All adult reconstruction surgeons at a single institution were approached to voluntarily provide patients with chlorhexidine gluconate-impregnated cloths and a printed sheet instructing their use the night before and morning of surgery. Records for all knee arthroplasties performed between January 2007 and December 2008 were reviewed to determine the incidence of deep incisional and periprosthetic surgical site infections. Overall, the advance pre-operative protocol was used in 136 of 912 total knee arthroplasties (15%). A lower incidence of surgical site infection was found in patients who used the advance cutaneous preparation protocol as compared to patients who used the in-hospital protocol alone. These findings were maintained when patients were stratified by surgical

infection risk category. No surgical site infections occurred in the 136 patients who completed the protocol as compared to 21 infections in 711 procedures (3.0%) performed in patients who did not. Patient-directed skin disinfection using chlorhexidine gluconate-impregnated cloths the evening before, and the morning of, elective knee arthroplasty appeared to effectively reduce the incidence of surgical site infection when compared to patients who underwent in-hospital skin preparation only.

Introduction

Knee arthroplasty remains among the most successful and reliable procedures for decreasing pain and improving function by reliably providing excellent outcomes in greater than 90% of patients at follow-up times of ten to 15 years [3, 14, 18]. Nevertheless, complications occur that can have profound consequences for both patients and surgeons, with surgical site infections being among the most common. They are among the most devastating complications, frequently requiring a prolonged treatment period lasting several months, with multiple surgical procedures necessary to eradicate the infection. While a range of values have been reported, the two largest reported patient series suggest an incidence of peri-prosthetic infection following primary knee arthroplasty of between one and two percent [12, 13], rising to up to ten percent following revision knee arthroplasty.

A number of different strategies have been developed and reported for reducing the incidence of surgical site infections following knee arthroplasty. In elective surgical procedures, infections have been postulated to occur commonly as a result of intra-operative colonisation of the wound with native skin flora [4, 10, 15, 17], and a number of innovations and procedural changes have focused on

M. G. Zywił • R. E. Delanois • Q. Naziri • A. J. Johnson •
M. A. Mont

Center for Joint Preservation and Replacement, Rubin Institute
for Advanced Orthopedics, Sinai Hospital of Baltimore,
Baltimore, MD, USA

J. A. Daley
Infection Prevention and Control, Sinai Hospital of Baltimore,
Baltimore, MD, USA

M. A. Mont (✉)
Rubin Institute for Advanced Orthopedics, Center for Joint
Preservation and Reconstruction, Sinai Hospital of Baltimore,
2401 West Belvedere Avenue,
Baltimore, MD 21215, USA
e-mail: mmont@lifebridgehealth.org

reducing this source of contamination. In addition to the long-standing practice of skin disinfection immediately prior to patient draping on the operating table, other prophylactic measures include pre-operative clipping of skin hair in the vicinity of the operative field [20] and the application of adhesive antimicrobial incise drapes [1]. However, all of these strategies are limited to the area of the incision, whereas the rest of the patient's skin does not undergo disinfection. While whole body bathing with antiseptic has been shown to reduce the bacterial load of the skin as well as the acquisition of infections in intensive care settings [2, 5, 21], this strategy presents challenges including: difficulties in achieving entire body coverage and in maintaining sufficiently high concentrations of solution on the skin following the wash for effective antisepsis [7]. Although the US Centres for Disease Control recommend that surgical patients be required to shower or bathe with an antiseptic agent the night before the operative day [16], there may be poor compliance when these efforts are patient-directed, and there are high costs if this is directed by the health care staff. Recently, a new no-rinse chlorhexidine-impregnated cloth has been developed which allows longer-term maintenance of an effective chlorhexidine concentration on the skin [8], potentially reducing skin floral loads if appropriately used prior to surgery. These cloths are also easy to use, potentially enabling patient-directed advance skin preparation without requiring the assistance of a trained allied health care worker or early admission to the hospital.

The purpose of this study was to evaluate the incidence of deep surgical site infections in knee arthroplasty patients who completed an advance pre-operative cutaneous surgical preparation protocol and who were compared to patients who underwent standard peri-operative disinfection only. The secondary purposes were to compare the infection rates between the two groups when stratified by surgical infection risk category.

Materials and methods

A single institution's infection tracking database was reviewed to identify those patients who underwent an elective aseptic uni-, bi- or tricompartmental primary or

revision knee arthroplasty between 1 January 2007 and 31 December 2008. During this time, all the arthroplasty surgeons at the institution were encouraged to provide their patients with a standard self-directed advance pre-operative skin preparation protocol, which will be described later in more detail. A total of 912 patients were identified who underwent knee arthroplasty without a pre-operative suspected active joint infection. Sixty-five knee arthroplasty patients only partly complied with the advance preparation protocol, leaving 835 patients in the study. Of those, 136 knee arthroplasty patients completed the full advance protocol, while 711 underwent standard in-hospital preparation only. Mean patient age, gender distribution, mean body mass index and surgical infection risk category were similar for both groups (see Table 1). Institutional Review Board approval was sought and granted for this study.

During this time, all arthroplasty surgeons at the institution were asked to provide their patients with a standard self-directed advance pre-operative skin preparation protocol, along with 12 commercially produced 2% chlorhexidine-impregnated cloths for use as part of this treatment (Sage Products Inc., Cary, IL, USA). The protocol did not require showering or bathing the night before surgery, but if patients wished to do so, they were instructed to wait at least two hours following bathing prior to skin disinfection. Six washcloths were used the evening before surgery (Fig. 1): one for disinfecting the neck, chest and abdomen, one for the arms, one for each leg, one for the back and one for the surgical site. Patients were instructed to wipe their body down using the cloths, disinfecting the surgical site last and wiping back and forth for at least 3 minutes. Patients were to air dry for one minute before getting dressed and were instructed not to rinse, shower or apply any powder or cream following disinfection. The same procedure was followed the morning of surgery prior to departing for the hospital.

All patients were asked to remove adhesive stickers from the cloth packages at the time of disinfection and affix them to the protocol instruction sheet, which they then brought with them to the hospital as a means of confirming compliance. In addition, patients were further questioned concerning their compliance with the advance preparation protocol on the day of surgery. Patients were stratified into one of three groups: those who completed the advance

Table 1 Comparison of demographic factors of patient groups

	Advance prep compliant patients	No advance prep patients
Mean age, years (range)	63 (37–89)	63 (20–90)
Ratio of gender (men to women)	34:66	31:69
Mean body mass index, kg/m ² (range)	34 (20–55)	33 (17–59)
Ratio of risk category (low to medium to high)	34:35:31	34:41:25

Fig. 1 Graphical instructions for the use of the advance cutaneous preparation protocol

© 2010 Sinai Hospital of Baltimore

protocol both the evening before and morning of surgery, those who did not follow the protocol and underwent in-hospital preparation only and those who complied only partly with the advance protocol (either the morning of surgery or the evening before, but not both).

Following admission, all patients then underwent the same peri-operative skin disinfection procedure regardless of advance protocol compliance status. This consisted of antiseptic painting of the surgical site following induction of anaesthesia and positioning on the operating table with alcohol only, followed by combination iodine povacrylex/alcohol (DuraPrep solution, 3M, St. Paul, MN, USA). All patients underwent surgical, post-operative and follow-up care as per their surgeon's standard protocols.

For the purpose of this study, a deep surgical site infection was defined as either a deep incisional or joint space infection occurring within one year of the surgical procedure and with the infection appearing to be related to the surgical procedure (defined as an absence of a focus of infection or precipitating event unrelated to the index arthroplasty). This definition is based on the guidelines published by the US Centres for Disease Control, with the exception that superficial wound infections that did not progress to a deeper location were not considered to be a surgical site infection, as these can typically be managed without the need for an arthrotomy or component revision.

The overall incidence of deep surgical site infections was compared between patients who completed the advance pre-

operative skin preparation protocol and those who did not, as well as to those who were partially compliant (morning of surgery only). In addition to a comparison of the overall infection rates, the results for compliant and non-compliant patients were stratified by the surgical infection risk category. Surgical infection risk categorisation was performed using a modified methodology described by Haley et al. and Culver et al., and recommended by the National Nosocomial Infections Surveillance System [6, 11]. Patients were stratified into one of three risk categories: low risk, medium risk and high risk. The distribution of surgical risk categories was similar between the two groups ($p=0.245$). A description of the categories can be found in Table 2.

Results

Overall, there was a considerably lower incidence of surgical site infections in patients who complied with the advance skin preparation protocol compared to those who underwent in-hospital preparation only. There were no surgical site infections among 136 patients who used the advance protocol compared to 21 infections in 711 patients (3.0%) who used the in-hospital preparation only. The incidence of surgical site infections in patients who were partially compliant with the protocol was in between that found in fully compliant and non-compliant individuals (1 infection in 65 patients, 1.5%).

Table 2 Surgical wound infection risk categorisation

	Score	
Wound class		
Clean or clean-contaminated	0	
Contaminated, dirty	1	
American Society of Anesthesiologists score		
< 3	0	
3 +	1	
Surgical cut time		
< 2 h	0	
≥ 2 h	1	
Total score	0:	Low risk
	1:	Moderate risk
	2, 3:	High risk

When patients were stratified by infection risk category, a markedly lower incidence of infection was seen in patients who underwent the pre-operative protocol for all three risk categories: low risk (0 versus 1.6%), medium risk (0 versus 2.4%) and high risk (0 versus 7.3%). A full description of results stratified by risk category can be found in Table 3.

Discussion

Considerable recent attention has been placed on the accurate diagnosis and effective treatment of peri-prosthetic infections in the field of joint arthroplasty surgery. These have included the use of various serological markers for diagnosis and the use of two-stage revision procedures with the use of local and systemic antibiotic therapy for both eradication of infection and prophylaxis against re-infection. However, less attention has been paid to developing new strategies to prevent the peri-prosthetic infections, despite the fact that the commonly reported incidence ranges from 1% to as high as 10% depending on the type of procedure. With some recent reports suggesting that the use of no-rinse

chlorhexidine-impregnated cloths for advance skin preparation may reduce surgical site infection rates, we wanted to determine whether a patient-directed advance protocol could reduce the incidence of peri-prosthetic infections in knee arthroplasty.

We acknowledge that the patients were not truly randomised to the two study arms; rather, all surgeons were encouraged to provide the protocol and cloths to their patients, but participation was voluntary. However, the distribution of surgical infection risk categories was similar between the two groups, and we believe that this study suggests that the use of an advance no-rinse chlorhexidine cloth skin preparation protocol can reduce the incidence of peri-prosthetic infections following knee arthroplasty. Nevertheless, a prospectively randomised study with larger numbers of patients should be performed to further confirm this finding.

We had similar findings to Eiselt who compared the incidence of surgical site infection in 727 patients who had been instructed to use a povidone-iodine wash prior to the procedure to 736 total joint arthroplasty patients who were instructed to use a chlorhexidine cloth to disinfect the surgical site the night before and morning of surgery [9]. The author reported a decrease in the rate of surgical site infections from 3.19% with the povidone-iodine wash to 1.59% with the chlorhexidine cloth. Compliance rates were not measured, although the author stated that the hospital nurses reported better compliance with the chlorhexidine cloth. However, unlike the protocol reported by Eiselt, the one in our study included full body disinfection, rather than the surgical site only. It is possible that this additional disinfection contributed to the lower incidence of surgical site infections seen in our study.

Several authors have evaluated the use of chlorhexidine skin disinfection in reducing infection rates in patients receiving invasive treatment. Climo et al. compared the infection rates of intensive care unit patients following daily bathing with either soap and water (2,670 patients) or chlorhexidine solution (2,650 patients) over a one year period [5]. The authors reported a significantly lower incidence of acquisition of methicillin-resistant *Staphylo-*

Table 3 Incidence of surgical site infection stratified by risk category

Risk category	Compliance	Knees		
		Total joints operated	Number infected joints	Incidence (%)
Low	Non-compliant	256	4	1.6
	Compliant	52	0	0
Medium	Non-compliant	332	9	2.7
	Compliant	54	0	0
High	Non-compliant	123	9	7.3
	Compliant	30	0	0

coccus aureus (32%, $p=0.046$) and vancomycin-resistant *Enterococcus* (50%, $p=0.008$) as well as a lower incidence of vancomycin-resistant *Enterococcus* bacteraemia ($p=0.02$). Bleasdale et al. performed a similar comparison in patients admitted to the medical intensive care unit of a single institution [2], finding a significantly lower incidence of primary bloodstream infections in 391 patients washed daily with chlorhexidine-impregnated cloths as compared to 445 patients bathed daily with soap and water (9 versus 21 infections, $p=0.01$).

Swenson et al. compared the surgical infection rates following operating room skin preparation with one of three solutions: (1) povidone-iodine scrub and paint, (2) 2% chlorhexidine/70% isopropyl paint and (3) iodine povacrylex paint [19]. The authors found a significantly higher post-operative infection rate with the use of the chlorhexidine preparation (8.2%) as compared to the other regimens (both 4.8%, $p=0.001$). However, in a randomised comparison study of inguinal skin preparation in healthy volunteers using either a 2% chlorhexidine-impregnated cloth or 4% chlorhexidine scrub, Edmiston et al. found that the scrub preparation rapidly lost effectiveness, failing to meet US Food and Drug Administration microbial reduction levels ten minutes after preparation [8]. It is possible that the findings reported by Swenson et al. would have differed had the authors used a chlorhexidine-impregnated cloth rather than a liquid preparation.

Conclusions

The use of an advance skin preparation protocol consisting of patient-directed use of a no-rinse chlorhexidine-impregnated cloth the evening before and morning of surgery appeared to have substantially decreased the incidence of deep surgical site infection in elective knee arthroplasty. Further prospective study with a larger patient cohort is necessary to confirm these findings.

References

- Alexander JW, Aerni S, Plettner JP (1985) Development of a safe and effective one-minute preoperative skin preparation. *Arch Surg* 120:1357–1361
- Bleasdale SC, Trick WE, Gonzalez IM, Lyles RD, Hayden MK, Weinstein RA (2007) Effectiveness of chlorhexidine bathing to reduce catheter-associated bloodstream infections in medical intensive care unit patients. *Arch Intern Med* 167:2073–2079. doi:10.1001/archinte.167.19.2073
- Buechel FF Sr, Buechel FF Jr, Pappas MJ, Dalessio J (2002) Twenty-year evaluation of the New Jersey LCS Rotating Platform Knee Replacement. *J Knee Surg* 15:84–89
- Byrne AM, Morris S, McCarthy T, Quinlan W, O'Byrne JM (2007) Outcome following deep wound contamination in cemented arthroplasty. *Int Orthop* 31:27–31. doi:10.1007/s00264-006-0121-z
- Climo MW, Sepkowitz KA, Zuccotti G, Fraser VJ, Warren DK, Perl TM, Speck K, Jernigan JA, Robles JR, Wong ES (2009) The effect of daily bathing with chlorhexidine on the acquisition of methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and healthcare-associated bloodstream infections: results of a quasi-experimental multicenter trial. *Crit Care Med* 37:1858–1865. doi:10.1097/CCM.0b013e31819ffe6d
- Culver DH, Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG, Banerjee SN, Edwards JR, Tolson JS, Henderson TS et al (1991) Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. *Am J Med* 91:152S–157S
- Edmiston CE Jr, Krepel CJ, Seabrook GR, Lewis BD, Brown KR, Towne JB (2008) Preoperative shower revisited: can high topical antiseptic levels be achieved on the skin surface before surgical admission? *J Am Coll Surg* 207:233–239. doi:10.1016/j.jamcollsurg.2007.12.054
- Edmiston CE Jr, Seabrook GR, Johnson CP, Paulson DS, Beausoleil CM (2007) Comparative of a new and innovative 2% chlorhexidine gluconate-impregnated cloth with 4% chlorhexidine gluconate as topical antiseptic for preparation of the skin prior to surgery. *Am J Infect Control* 35:89–96. doi:10.1016/j.ajic.2006.06.012
- Eiselt D (2009) Presurgical skin preparation with a novel 2% chlorhexidine gluconate cloth reduces rates of surgical site infection in orthopaedic surgical patients. *Orthop Nurs* 28:141–145. doi:10.1097/NOR.0b013e3181a469db
- Fairclough JA, Johnson D, Mackie I (1986) The prevention of wound contamination by skin organisms by the pre-operative application of an iodophor impregnated plastic adhesive drape. *J Int Med Res* 14:105–109
- Haley RW, Culver DH, Morgan WM, White JW, Emori TG, Hooton TM (1985) Identifying patients at high risk of surgical wound infection. A simple multivariate index of patient susceptibility and wound contamination. *Am J Epidemiol* 121:206–215
- Kurtz SM, Lau E, Schmier J, Ong KL, Zhao K, Parvizi J (2008) Infection burden for hip and knee arthroplasty in the United States. *J Arthroplasty* 23:984–991. doi:10.1016/j.arth.2007.10.017
- Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J (2010) Prosthetic joint infection risk after TKA in the Medicare population. *Clin Orthop Relat Res* 468:52–56. doi:10.1007/s11999-009-1013-5
- Lachiewicz PF, Soileau ES (2009) Fifteen-year survival and osteolysis associated with a modular posterior stabilized knee replacement. A concise follow-up of a previous report. *J Bone Joint Surg Am* 91:1419–1423. doi:10.2106/JBJS.H.01351
- Lidwell OM, Lowbury EJ, Whyte W, Blowers R, Stanley SJ, Lowe D (1983) Bacteria isolated from deep joint sepsis after operation for total hip or knee replacement and the sources of the infections with *Staphylococcus aureus*. *J Hosp Infect* 4:19–29
- Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR (1999) Guideline for prevention of surgical site infection, 1999. Hospital Infection Control Practices Advisory Committee. *Infect Control Hosp Epidemiol* 20:250–278. doi:10.1086/501620, quiz 279–280
- Nickinson RS, Board TN, Gambhir AK, Porter ML, Kay PR (2010) The microbiology of the infected knee arthroplasty. *Int Orthop* 34:505–510. doi:10.1007/s00264-009-0797-y
- Ritter MA, Berend ME, Meding JB, Keating EM, Faris PM, Crites BM (2001) Long-term followup of anatomic graduated components posterior cruciate-retaining total knee replacement. *Clin Orthop Relat Res* 388:51–57
- Swenson BR, Hedrick TL, Metzger R, Bonatti H, Pruett TL, Sawyer RG (2009) Effects of preoperative skin preparation on

- postoperative wound infection rates: a prospective study of 3 skin preparation protocols. *Infect Control Hosp Epidemiol* 30:964–971. doi:[10.1086/605926](https://doi.org/10.1086/605926)
20. Tanner J, Woodings D, Moncaster K (2006) Preoperative hair removal to reduce surgical site infection. *Cochrane Database Syst Rev* 3:CD004122. doi: [10.1002/14651858.CD004122.pub3](https://doi.org/10.1002/14651858.CD004122.pub3)
21. Vernon MO, Hayden MK, Trick WE, Hayes RA, Blom DW, Weinstein RA, Chicago Antimicrobial Resistance Project (CARP) (2006) Chlorhexidine gluconate to cleanse patients in a medical intensive care unit: the effectiveness of source control to reduce the bioburden of vancomycin-resistant enterococci. *Arch Intern Med* 166:306–312. doi:[10.1001/archinte.166.3.306](https://doi.org/10.1001/archinte.166.3.306)